PB-243 405

NORTHERN GREAT PLAINS RESOURCES PROGRAM: POSSIBLE DEVELOPMENT OF WATER FROM MADISON GROUP AND ASSOCIATED ROCK IN POWDER RIVER BASIN, MONTANA-WYOMING

Frank A. Swenson

Northern Great Plains Resource Program

Prepared for:

Geological Survey
Department of Agriculture

1 July 1974

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198010

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Approved for publication
by the Director,
U.S. Geological Survey

NATIONAL TECHNICAL
INFORMATION SERVICE

July 1, 1974

35

BIBLIOGRAPHIC DATA SHEET	1. Report No. NGPRP/GD-77/006	2.	3. Recipient's Accession No. PB243405
4. Title and Subtitle Northern Great Plains Resources Program Possible Development of Water from Madison Group and Associated Rock in Powder River Basin, Montana-Wyoming			5. Report Date July 1, 1976 6.
7. Author(s) Irma A. Swenson			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Northern Great Plains Resources Program Bldg. 67, Room C206 Denver Federal Center Denver, Colorado 80225			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Department of Interior, Department of Agriculture, Environmental Protection Agency, States of Montana, Nebraska, North Dakota, South Dakota, Wyoming			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

Presents an analysis of information on the Madison and associated water bearing strata underlying portions of Eastern Wyoming and Montana. The analyses indicates that there may be a potential for developing the deep ground water resource as a supply for coal conversion facilities. Maps are included which provide data on: 1) Depth to the water bearing strata; 2) The thickness of the Madison and associated water bearing strata; 3) Data on the total dissolved solids content of the water; and 4) The elevation to which water may rise in cased wells. An analysis of cost per acre foot is presented on nine locations corresponding to siting of power plants and synthetic natural gas conversion plants. Further research needs are listed.

17. Key Words and Document Analysis. 17a. Descriptors

Northern Great Plains
North Dakota
Ground Water
Water
Coal
Development
Water Sources
Availability
Montana
Wyoming
Deep Ground Water
Industry Use
Energy
Impacts
Water Alternatives

17b. Identifiers/Open-Ended Terms

17c. COSATI Field Group

PRICES SUBJECT TO CHANGE

18. Availability Statement No restriction on distribution.	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 39
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.75 - 3.25

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

THIS REPORT WAS PREPARED PURSUANT TO A DIRECTIVE DATED OCTOBER 23, 1973, FROM THE PROGRAM MANAGER, NORTHERN GREAT PLAINS RESOURCES PROGRAM. PUBLICATION OF THE FINDINGS AND RECOMMENDATIONS HEREIN SHOULD NOT BE CONSTRUED AS REPRESENTING EITHER THE APPROVAL OR DISAPPROVAL OF THE SECRETARY OF THE INTERIOR, THE SECRETARY OF AGRICULTURE OR THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY, OR THE STATES OF MONTANA, NEBRASKA, NORTH DAKOTA, SOUTH DAKOTA, AND WYOMING. THE PURPOSE OF THIS REPORT IS TO PROVIDE INFORMATION AND ASSISTANCE TO THE PROGRAM MANAGEMENT TEAM IN THE PREPARATION OF THE DRAFT INTERIM REPORT ON THE NORTHERN GREAT PLAINS RESOURCES PROGRAM. IT SHOULD BE NOTED THAT THE POTENTIAL OF THIS WATER SUPPLY IS UNDEFINED AND THE IMPACTS OF ITS POTENTIAL USES ARE UNKNOWN.

POSSIBLE DEVELOPMENT OF WATER FROM MADISON GROUP AND ASSOCIATED ROCKS IN POWDER RIVER BASIN, MONTANA-WYOMING

FRANK A. SWENSON

A recent study (1973-74) has indicated the potential for developing large ground-water supplies for industrial use in the Powder River Basin of Wyoming and Montana. Records of many oil tests and several water wells indicate that the Madison Group and the underlying carbonate rocks are hydrologically connected and transmit water as a unit. Also, in many localities, the overlying Tensleep and Minnelusa sandstones are also connected with the Madison. These rocks underlie the entire basin and are exposed on the flanks of the surrounding mountains. The Madison rocks, and to a considerable extent the underlying carbonates, are fractured and cavernous where exposed. Evidence that such conditions prevail in the subsurface is record of lost-circulation zones in drilling oil tests and the success of water wells in the Midwest, Wyoming area and on the flanks of the Black Hills. Large quantities of water have been derived from these rocks in the Midwest, Wyoming area since 1917, when the Tisdale well (T. 41 N., R. 81 W., sec. 16) yielding more than 4,000 gallons per minute was completed.

The Madison Group, which is considered the top part of the major aquifer of the basin, dips very steeply off the flanks of the Bighorn Mountains and is deeply buried along the mountain front for a considerable distance near Buffalo (see Plate No. 1 enclosed). The Madison dips away from the Black Hills at a more gentle gradient. This gradient continues almost across the basin to the deepest part, which lies close to the southwestern part of the basin. The top of the Madison is more than 10,000 feet below sea level in the deepest part of the basin about 25 miles east of Midwest, Wyoming. The top of the Madison gradually rises toward the north, and is between 4,000 and 5,000 feet below sea level under much of the Montana part of the basin.

The Madison Group is about 200 feet thick near the south end of the basin, but thickens to about 800 feet near the Wyoming-Montana boundary and is about 1,400 feet thick near the Yellowstone River (see Plate No. 2 enclosed).

The carbonate rocks underlying the Madison also thicken to the north from about 50 feet at the south end of the basin to as much as 600 feet at the state line. Because the Madison Group and the underlying carbonates are thick and in many places fractured and cavernous, the possibility for finding high porosity and permeability within the section is good. If permeability is sufficiently high, large-yield water wells can be developed in areas of significant aquifer thickness. Maps showing the altitude of the top of the Madison, and the thickness of the Madison and underlying carbonates, have been prepared and are enclosed.

The Madison and underlying carbonates contain water of moderate-to-good quality that is probably suitable for industrial use. Along the flanks of the Black Hills the water contains less than 1,000 milligrams per liter (mg/l) dissolved solids (see Plate No. 3 enclosed). A tongue of good-quality water extends northwest from the Black Hills into southern Montana. Under much of the remaining part of the Powder River Basin the water in the deep aquifers has less than 2,000 mg/l dissolved solids. In the Midwest and Glenrock areas, where there has been major development of the Madison, the mineralization of the water has increased since the first water wells were drilled, and an increase in mineralization of the water can be expected in any area of major water development.

Even though the water has only moderate-to-low mineralization and may be suitable for industrial use in energy development, it is marginal-to-unsatisfactory for irrigation or other specialized uses demanding water of good quality. Most of the analyses available of water from the Madison Group indicates that it contains too high a percentage of sodium for irrigation use. In general the water, except that near the Black Hills, does not meet the U.S. Public Health Service (1962) standards for use on interstate carriers, but it is used for the municipal water supply for Midwest, Newcastle, Upton, and Osage.

A map showing the elevation to which water will rise in tightly cased wells completed in the Madison Group is enclosed (see Plate No. 4 enclosed). This map provides data from which interpretations can be drawn pertaining to the location of recharge areas, direction of water movement, relative ability of the rock to furnish water to wells, and the results of major development of water from this aquifer. In general the gradient of the potentiometric

surface is steep on the west and southwest flanks of the basin, but is less steep on the flanks of the Black Hills. The much smaller gradients found throughout the central part of the basin indicate that either underflow is smaller or else the transmissivity is greater and therefore well yields would be larger.

The potentiometric map (see Plate No. 4 enclosed) indicates that major recharge to the Madison Group is derived from the Black Hills, the southern and northern ends of the Bighorn Mountains, and the Pryor Mountains south of Billings, Montana. In general the water moves to the north and northeast, but some water moves through the Madison to the southeast out of the Powder River Basin. Springs issue from the Madison on the flanks of the basin and streams flow across the outcrops of the Madison and other rocks where they are exposed, both of which indicate that most of the gound-water reservoir may be full.

Major ground-water development from the Madison Group will, to a considerable extent, consist of mining a resource because use may exceed recharge. If wells are put down near the center of the basin, where most of the strippable coal occurs, it will probably be many years before major water developments will have a significant effect on recharge areas. As mining of the water from the Madison takes place the artesian head will decline, pump lifts will continue to increase, and the cone of influence of the well field will enlarge. Well fields for major water development should be as widely spaced as possible to limit mutual interference. As an example, major water depletions in the Midwest, Wyoming area have been underway since 1917. This has resulted in reducing pressure heads a maximum of about 300 feet, in an area of influence that has extended under some six townships, as shown on the potentiometric map (see Plate No. 4 enclosed).

Virtually all the existing water wells are on or near the flanks of the Powder River Basin, where the Madison is thin and the gradients of the potentiometric surface are steep. Test holes drilled in areas where the Madison is thin may fail to yield much water. Larger well yields can be expected where thicker sections of the aquifer are available to supply water to wells, provided fractured or cavernous zones are penetrated. Water wells have not been drilled to the Madison in the deeper parts of the basin. However, drill-stem tests of some oil-exploration wells have indicated high permeability at depths exceeding 12,000 feet.

Virtually all water wells in the Powder River Basin are small-diameter holes having perforated casings similar to that used in oil fields. Such small-diameter wells have high entrance losses and pipe-friction losses when transmitting large quantities of water to the surface. Appropriate water-well design and construction will result in considerably larger yields. It should be recognized that the yield of individual wells may range widely. For example, the specific capacity of 27 wells ranged from less than 1.0 gallons per minute (gpm) per foot drawdown to 41 gallons per minute per foot drawdown at maximum observed yields. However, tests on one well that had a specific capacity of 41 gallons per minute per foot drawdown at a yield of 7,200 gallons per minute showed a specific capacity of 49 gallons per minute per foot drawdown at a yield of 1,700 gallons per minute. This indicates that proper well construction is imperative to minimize friction loss. Acidizing and other development work on wells may increase the yield several fold under favorable conditions.

Specific data on the transmissivity and storage coefficient of the Madison are not available for Wyoming. However at the Bell Creek oil field in Montana, recovery data from a water production well in sec. 22, T. 9 S., R. 53 E., indicated a transmissivity of 12,000 ft^3/day/ft. The average yield of the five wells at this location is about 1,700 gallons per minute through perforated casing. Data from drill-stem tests in several other Montana localities within the Powder River Basin indicate the transmissivity of the Madison ranges from 4.5 to 26,000 ft^3/day/ft.

Near Midwest, Wyoming, records are available for 14 wells that have been used to supply water for the oil industry. The deepest water well in this area is 10,040 feet and had an original yield of 810 gallons per minute. Available data show that the average original yield of seven wells drilled in the Midwest area was 3,800 gallons per minute. Yields of wells in this area initially ranged from 430 to more than 9,000 gallons per minute (initial drawdown data are not available).

Preliminary estimates of cost of wells, pumps, and other facilities to supply water for the proposed power and gasification plants have been prepared (see Table 1). Drilling contractors and operators, who have recently

been active in the area, provided data for estimates of costs involved in constructing wells. Pump manufacturers provided cost estimates for pumps meeting proposed needs. Estimated costs outlined reflect costs as of April 1974. Standby wells have been included, to provide water needed when a shutdown is required. Plans for storage at plant site call for open reservoirs having a capacity of more than 1 day's water supply. If the water is used mainly for cooling purposes then holding ponds will be required; perhaps if it becomes advantageous to use the hot water as it comes from the well, such storage would not be as important. Water from deep wells will have a temperature between 200° F (93° C) and 250° F (121° C) and thus can easily be converted to steam if distilled water is needed for process use.

Much more additional data regarding the Madison are needed before location and spacing of major water developments and their effects are known. At present there are no water wells in the central part of the Powder River Basin. Exploratory drilling and aquifer-performance tests in the parts of the basin where major strippable coal is found are required to determine if the hydrologic conditions are favorable for major water supplies before construction of facilities for energy development. Arrangements should be made whereby needed hydrologic data can be gained by close coordination between the planning, exploratory, and development programs.

The following estimates have been made for furnishing water supplies needed from deep ground-water sources for operation of the hypothetical power plants and coal gasification plants in the Powder River Basin (locations shown on Plate No. 8). To estimate costs, the following assumptions were made: (1) The average yield per well will be 2,000 gallons per minute with a miximum drawdown of 400 feet over a period of years, (this implies that there will be no interference losses between wells, and pumping levels will not exceed 400 feet); (2) For each site two standby wells are needed; (3) The estimated cost of drilling, $60 per foot, is based on 20-inch diameter casing to accommodate the pump at the anticipated setting, 13-5/8 inch inside diameter casing to the top of the Madison, and uncased hole thereafter; (4) Cost of power is 10 mills per kilowatt hour; and (5) The annual capitalization cost is based on 11.4 percent of capital investment, which includes administrative costs, interest during construction and costs amortized over 40 years at 8 percent. These estimates

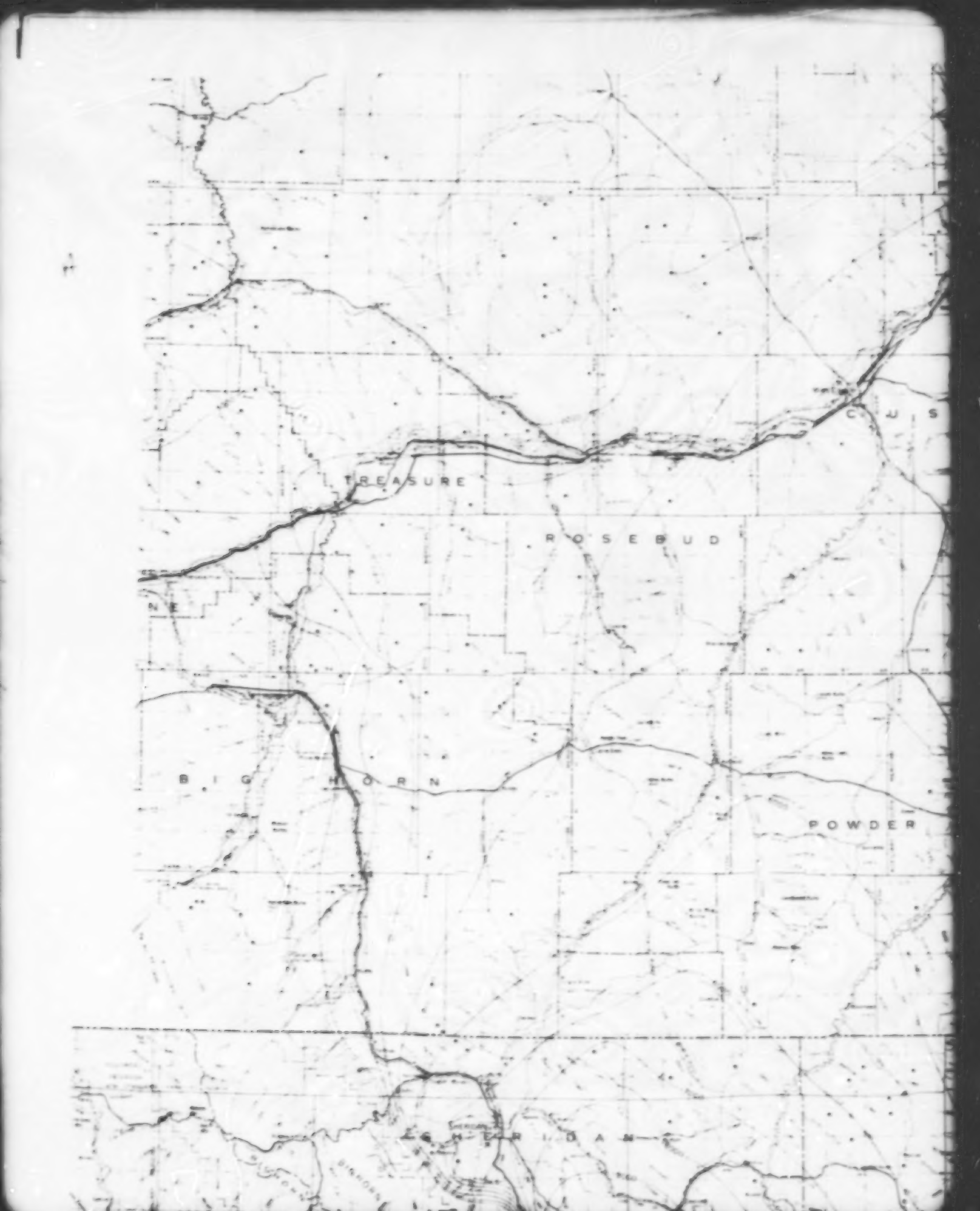
may vary significantly (as much as a factor of 2) from site to site, but serve to determine an order-of-magnitude of costs for ground-water development.

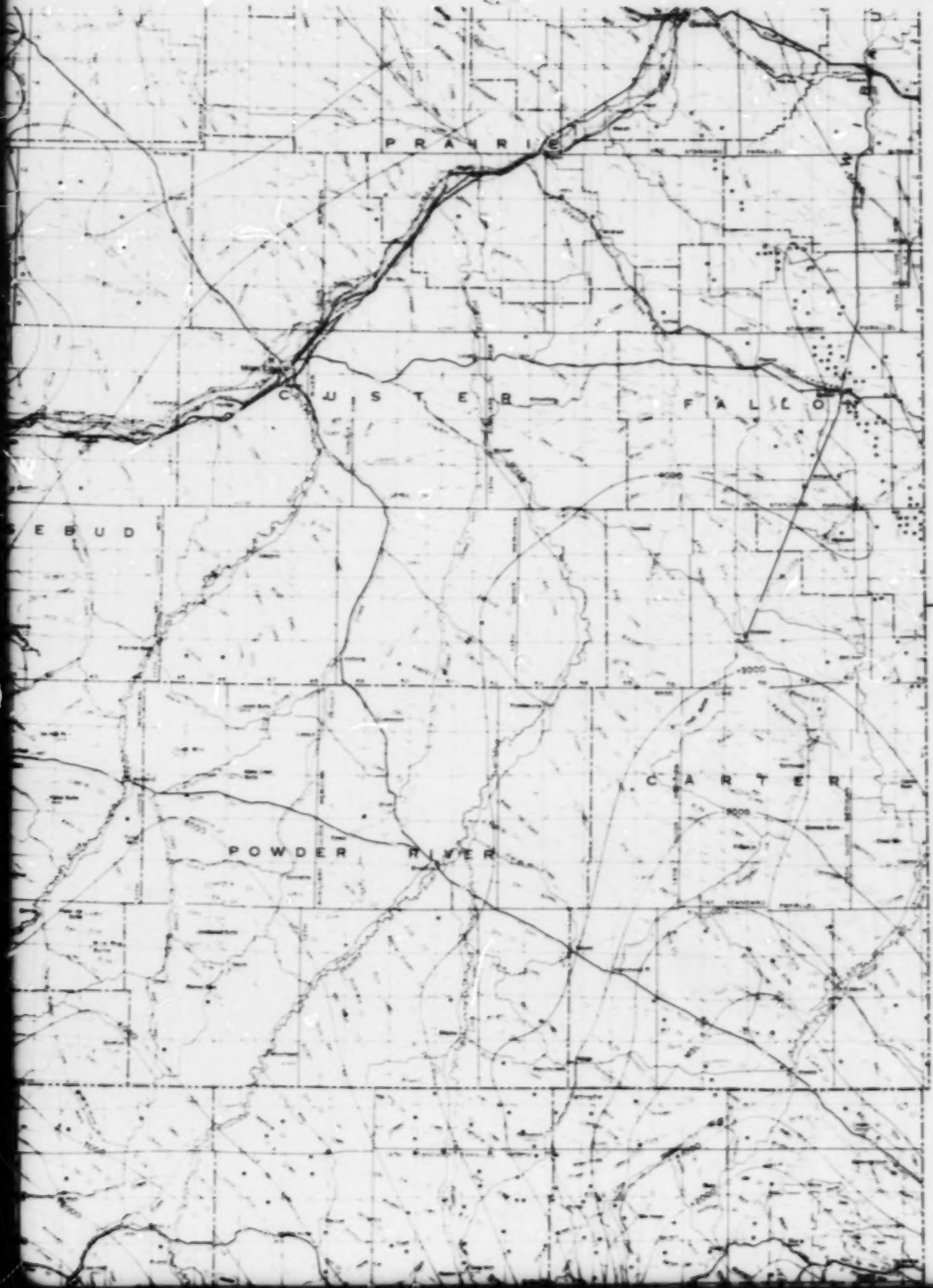
As previously stated, close coordination between planning, exploratory, and development programs must be maintained whereby needed hydrologic data can be obtained. Arrangements must be made to obtain significant data by means of logging commercially drilled test wells, whether they be for water or for oil and gas. Sonic, temperature, and other geophysical logs beyond those normally run by oil exploration companies, may provide useful information on the aquifer. Any test holes drilled to develop large supplies of water may provide useful information and it is planned that careful, detailed aquifer-performance tests will be performed.

Quantitative data on existing wells will be gathered and areawide analyses will be made of data so assembled. Data on step drawdown tests will prove useful where available, or where we can make such tests of existing wells.

PRELIMINARY ESTIMATES OF COST OF WELLS, PUMPS, AND RELATED FACILITIES TO SUPPLY WATER FOR PROPOSED POWER AND GASIFICATION PLANTS.

Site	Annual water requirement acre-feet	Static water level	Number of wells	Well costs	Number of pumps	Pump costs	Cost of collection and storage	Total capital costs	Capitalization based on 11.4 percent	Cost of pumping	Maintenance Annual	Total annual costs	Cost per acre-foot
Powerplant No. 1	23,000	150 feet below land surface	10 wells 11,000 ft ave. depth	$6,600,000	10	$300,000	$1,000,000	$ 7,900,000	$ 900,000	$150,000	$ 60,000	$1,110,000	$48
Powerplant No. 2	19,500	80 feet above land surface	9 wells 10,000 ft ave. depth	5,400,000	9	180,000	1,000,000	6,580,000	750,000	85,000	36,000	871,000	45
Powerplant No. 3	19,500	100 feet above land surface	9 wells 10,500 ft ave. depth	5,670,000	9	135,000	1,000,000	6,805,000	776,000	58,000	27,000	861,000	44
Powerplant No. 4	19,500	500 feet above land surface	9 wells 9,000 ft ave. depth	4,860,000	Wells will flow initially - No pumps		1,000,000	5,860,000	669,000	-	1,000	670,000	33
Gasification Plant No. 1	30,000	600 feet below land surface	12 wells 12,500 ft ave. depth	9,000,000	12	720,000	1,000,000	10,720,000	1,220,000	410,000	144,000	1,774,000	[illegible]
Gasification Plant No. 2	30,000	500 feet below land surface	12 wells 11,500 ft ave. depth	8,280,000	12	720,000	1,000,000	10,000,000	1,140,000	370,000	144,000	1,654,000	55
Gasification Plant No. 3	30,000	GROUND-WATER CONDITIONS AT THIS SITE ARE TOO UNCERTAIN TO ESTIMATE											
Gasification Plant No. 4	30,000	250 feet above land surface	12 wells 10,000 ft ave. depth	7,200,000	12	120,000	1,000,000	8,320,000	950,000	62,000	24,000	1,036,000	34
Gasification Plant No. 5	30,000	150 feet below land surface	12 wells 10,000 ft ave. depth	7,200,000	12	360,000	1,000,000	8,560,000	977,000	225,000	72,000	1,274,000	42
Gasification Plant No. 6	30,000	500 feet above land surface	12 wells 8,000 ft ave. depth	5,760,000	Wells will flow initially - No pumps		1,000,000	6,760,000	770,000	-	1,000	771,000	26
Gasification Plant No. 7	30,000	100 feet above land surface	12 wells 8,500 ft ave. depth	6,120,000	12	100,000	1,000,000	7,220,000	824,000	60,000	20,000	884,000	29
Gasification Plant No. 8	30,000	500 feet above land surface	12 wells 8,500 ft ave. depth	6,120,000	Wells will flow initially - No pumps		1,000,000	7,120,000	812,000	-	1,000	813,000	27
Gasification Plant No. 9	30,000	650 feet above land surface	12 wells 9,000 ft ave. depth	6,480,000	Wells will flow initially - No pumps		1,000,000	7,480,000	854,000	-	1,000	855,000	28


TREASURE
ROSEBUD
BIG HORN
POWDER


PRAIRIE
CUSTER
FALLON
EBUD
CARTER
POWDER RIVER

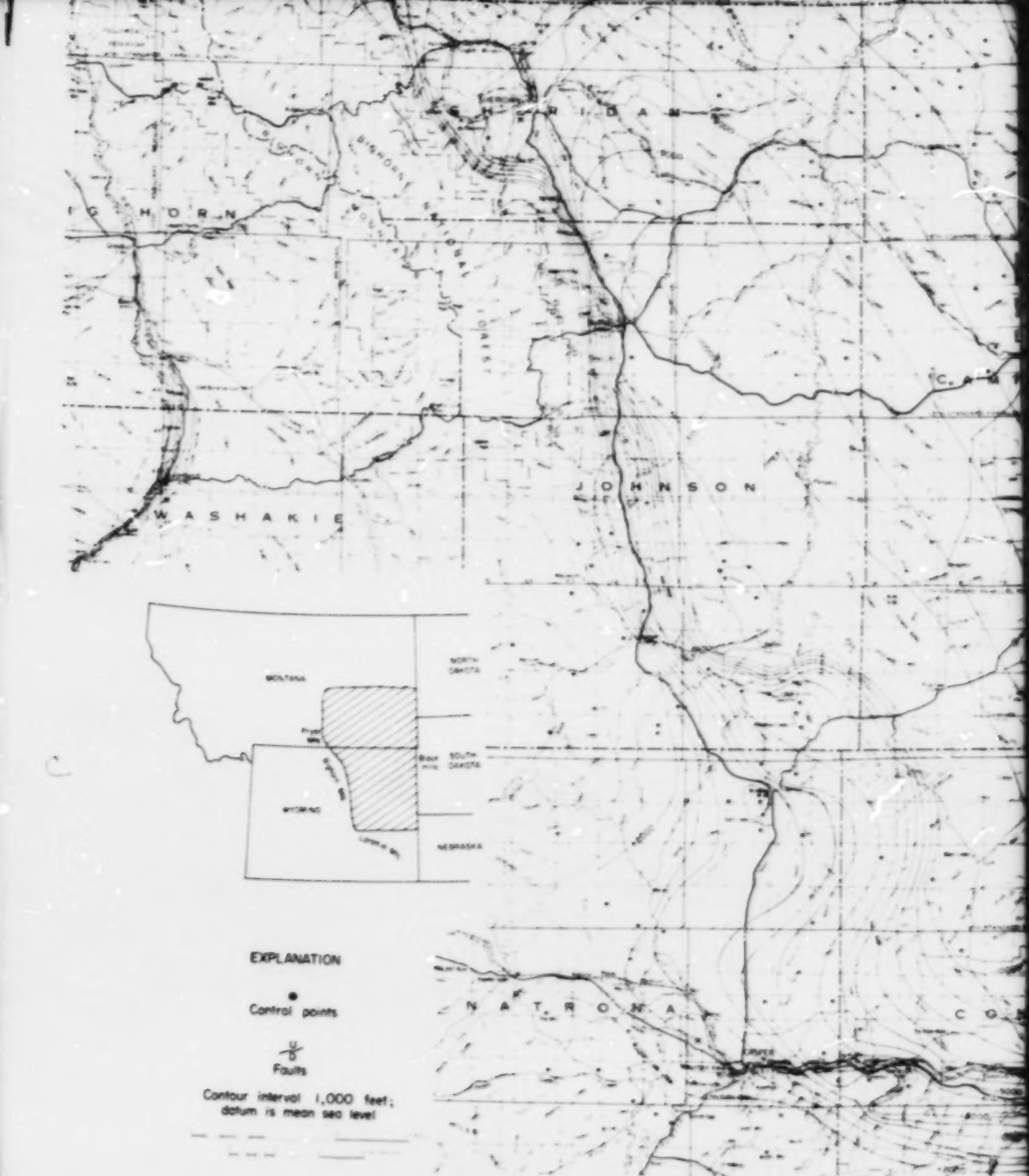
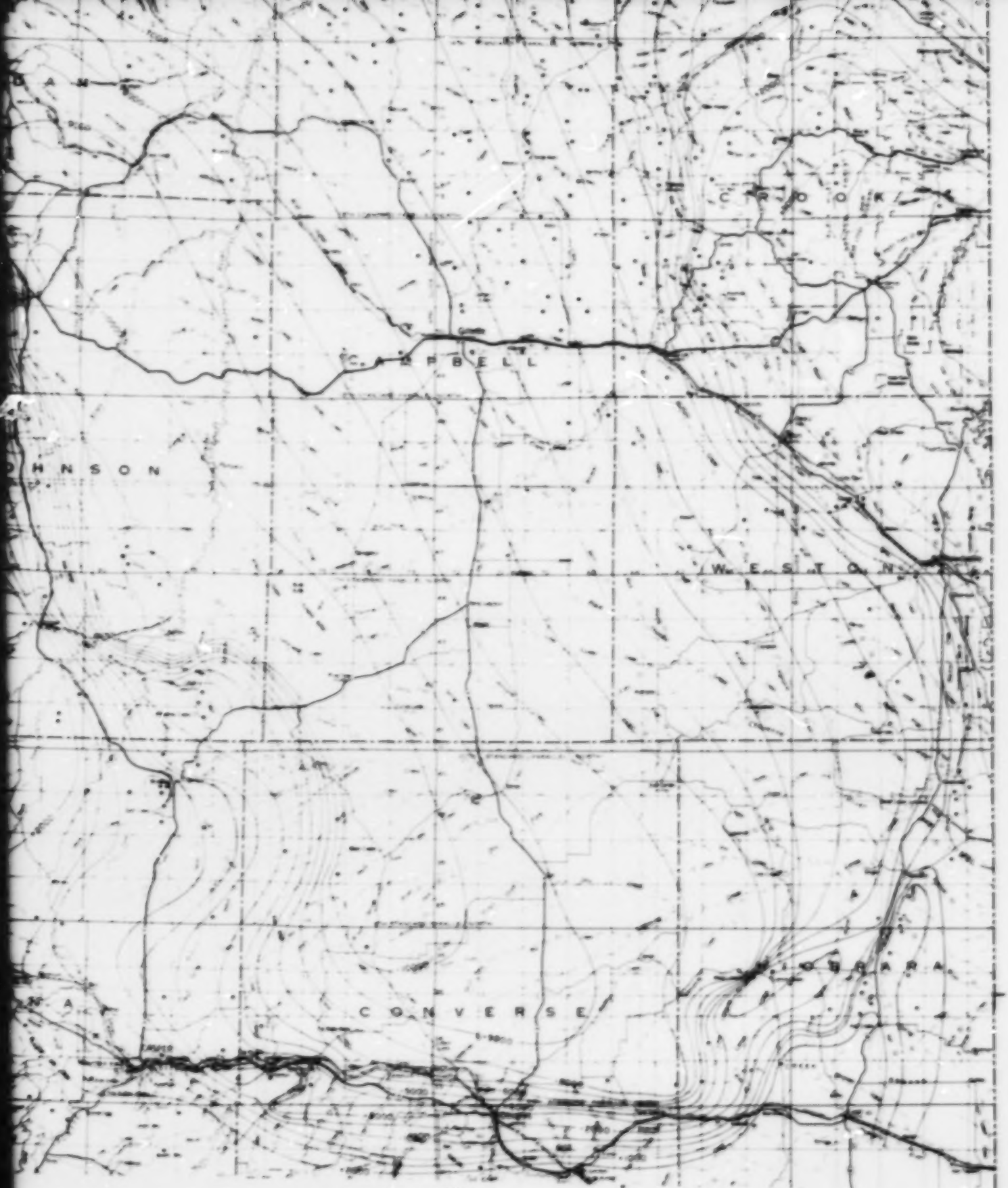


PLATE 1 - STRUCTURE CONTOURS ON TOP OF MADISO



ONTOURS ON TOP OF MADISON GROUP

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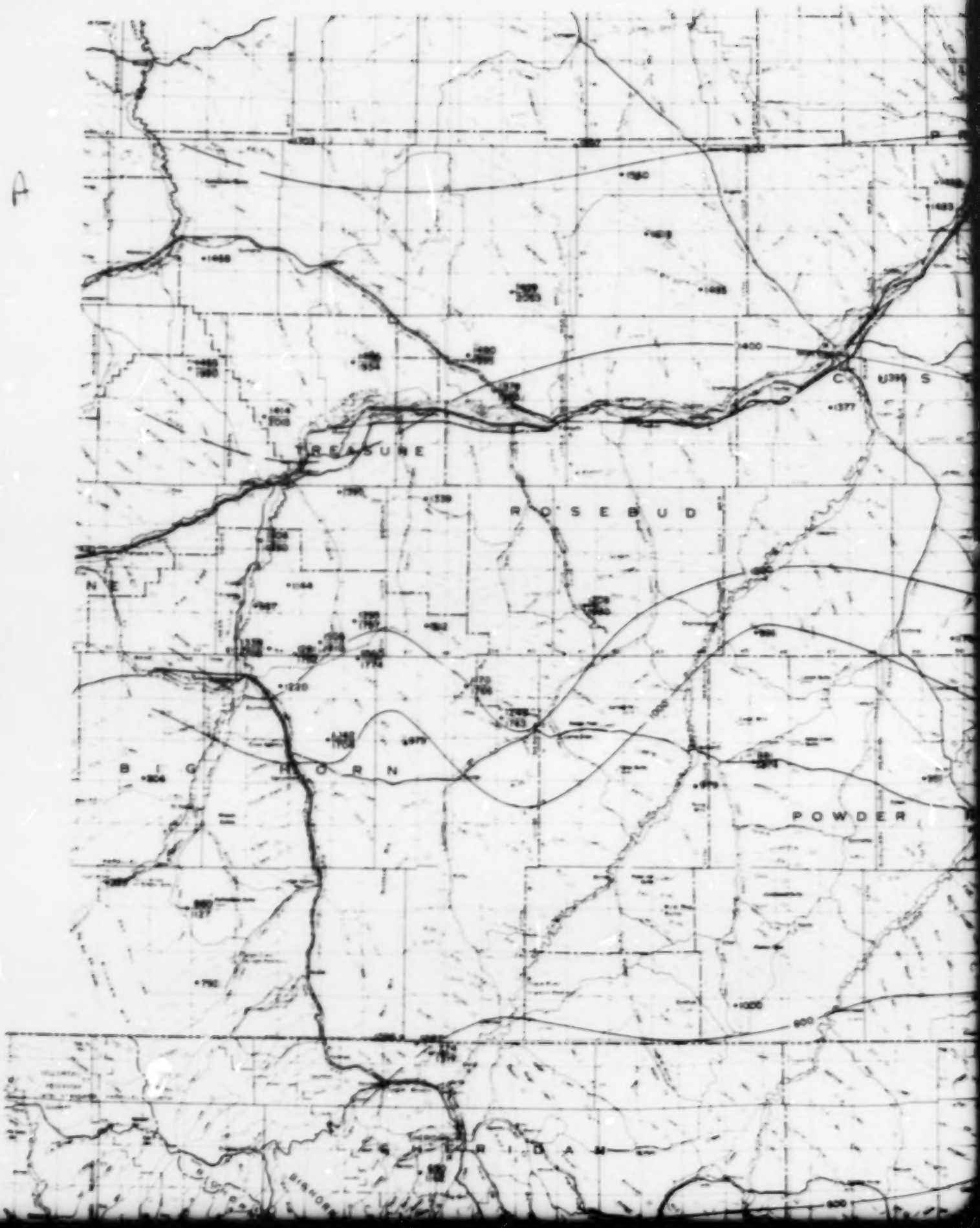
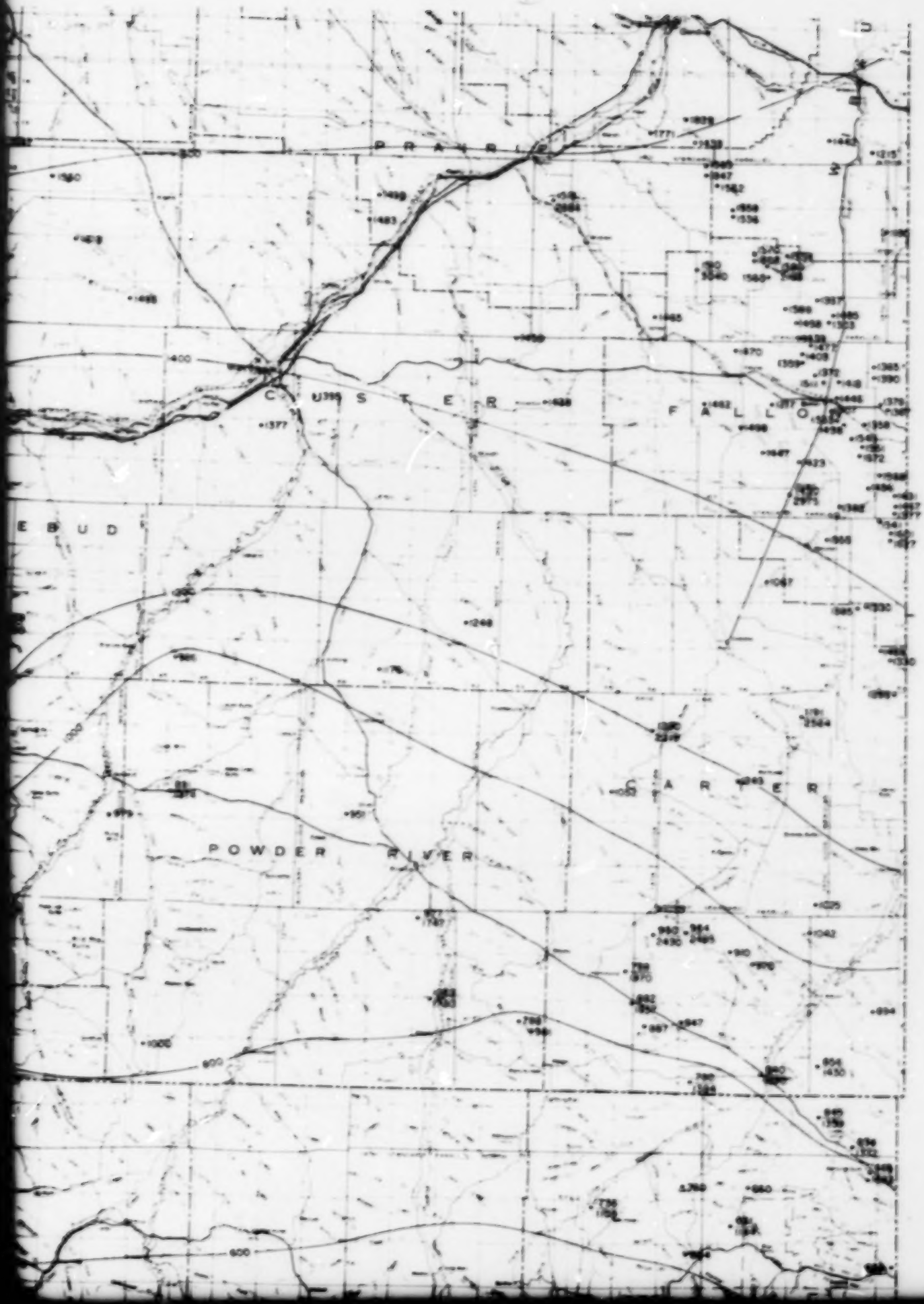

TREASURE
ROSEBUD
BIG HORN
POWDER


P R A I R I E
C U S T E R
F A L L O
E B U D
C A R T E R
POWDER RIVER

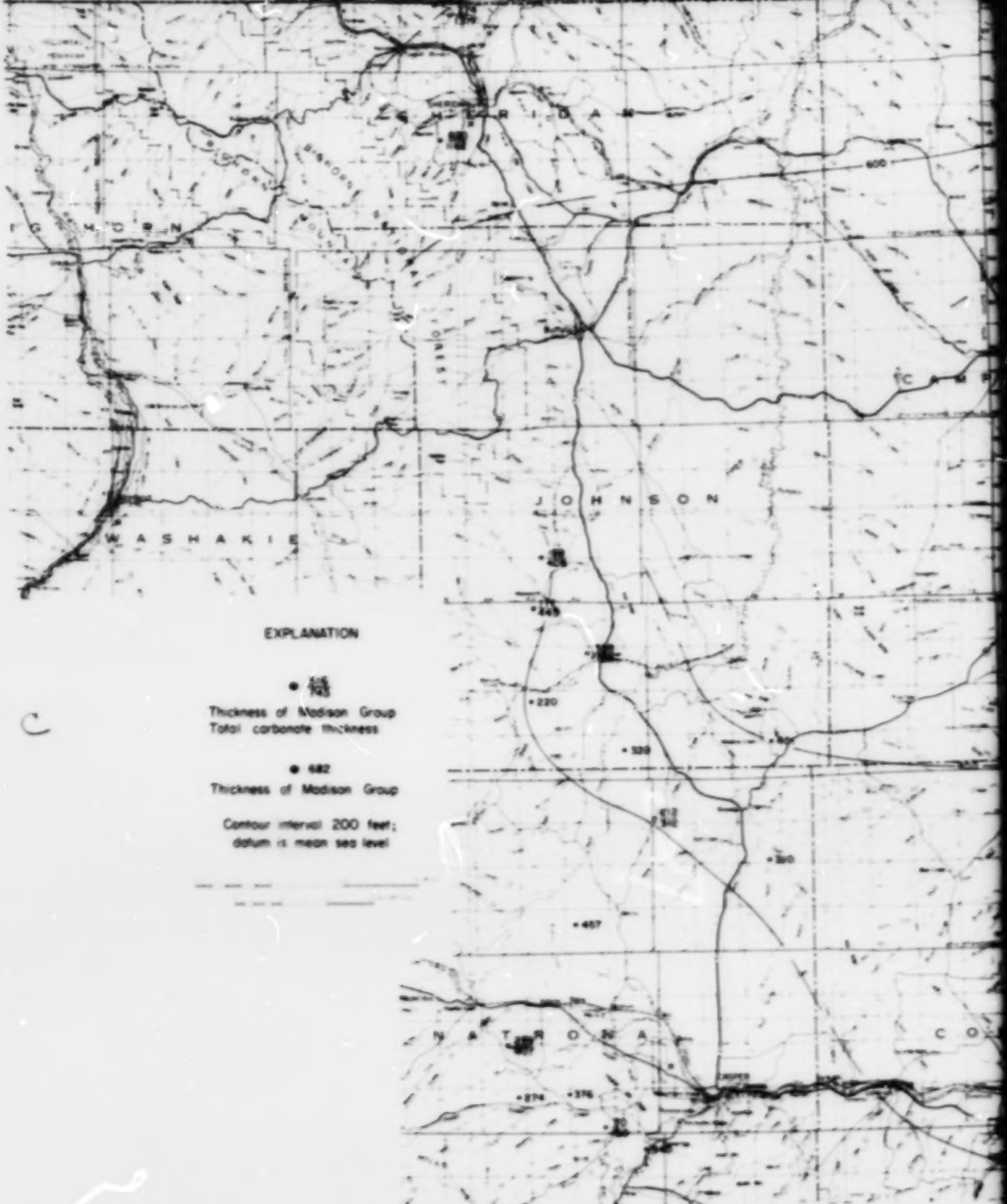
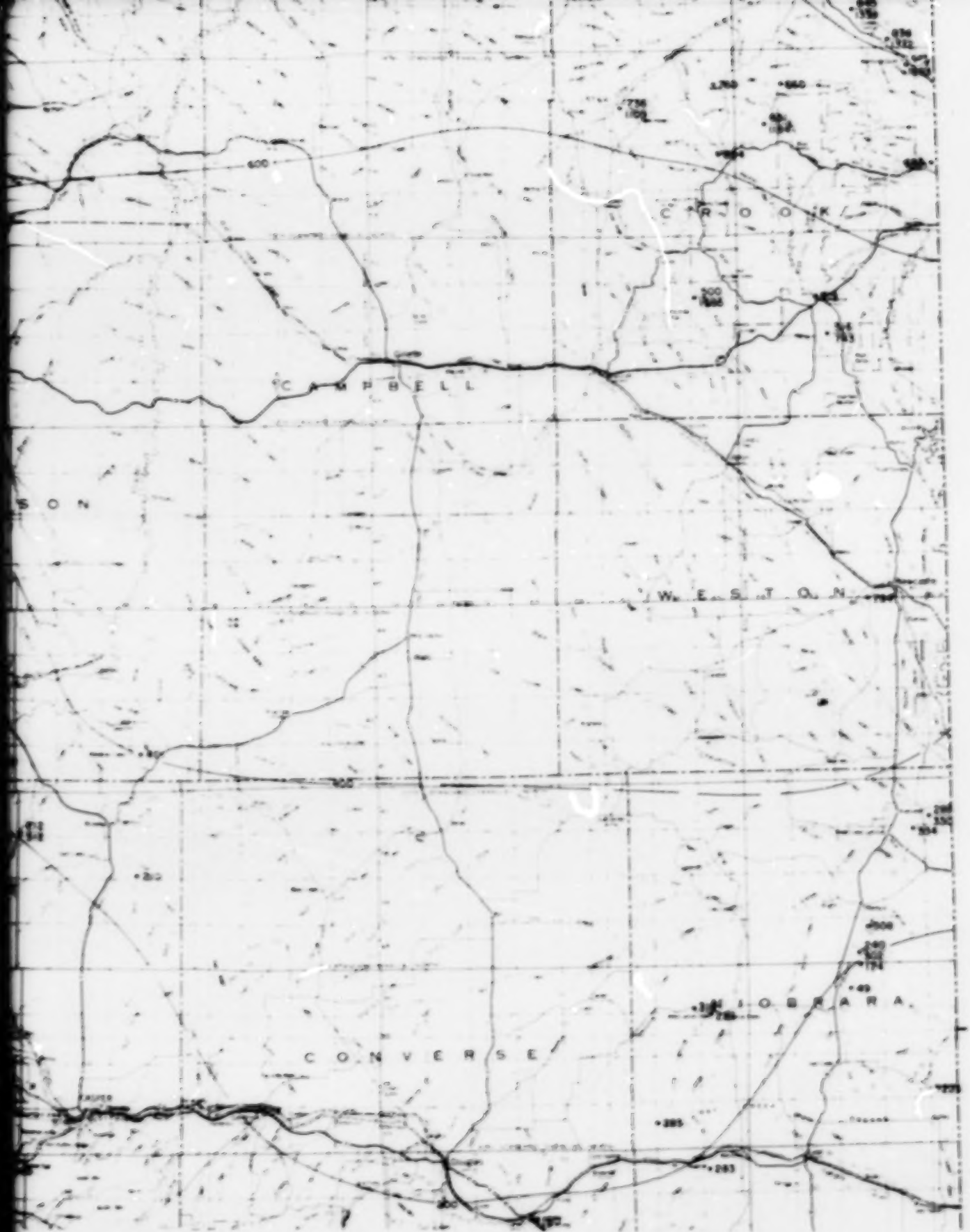
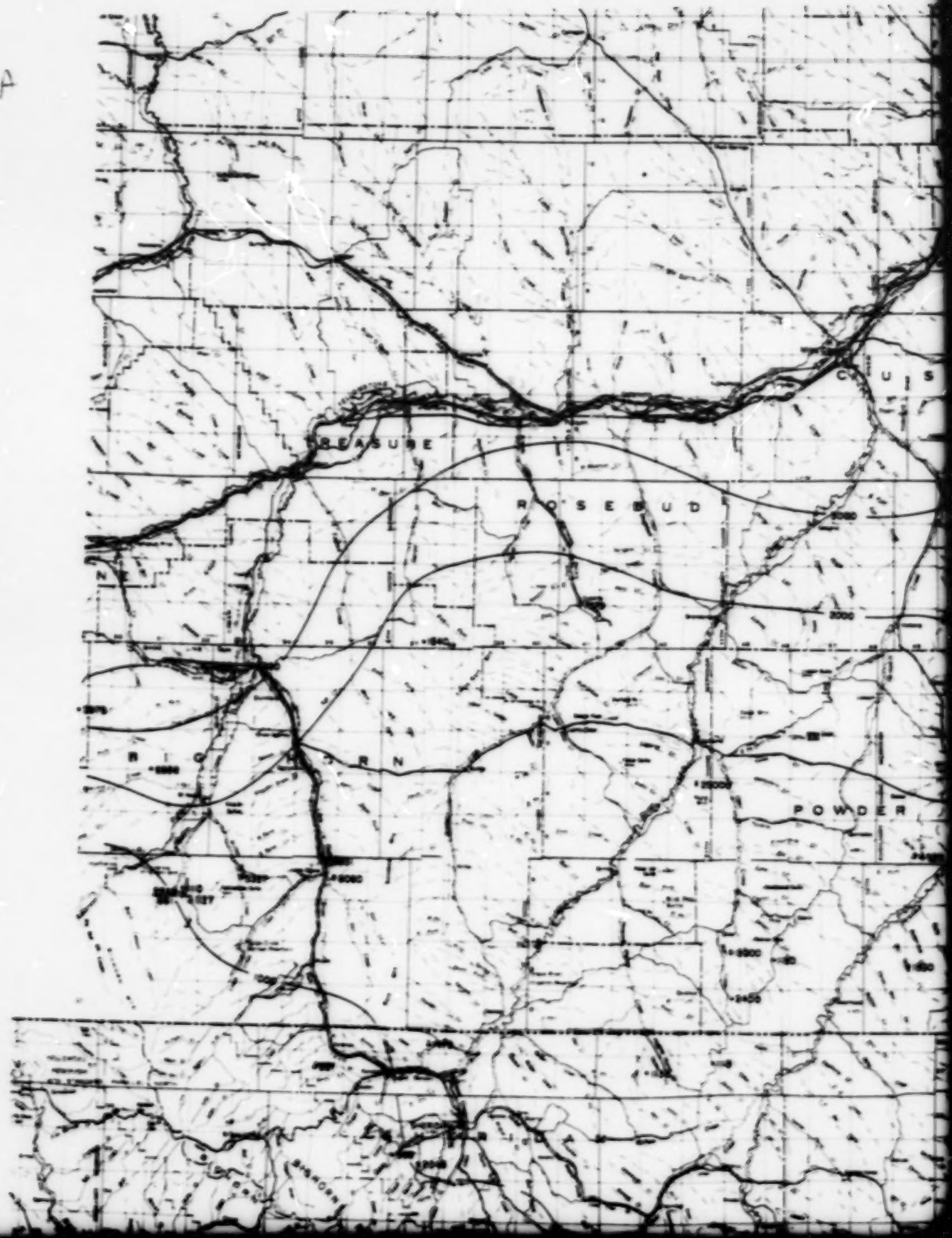


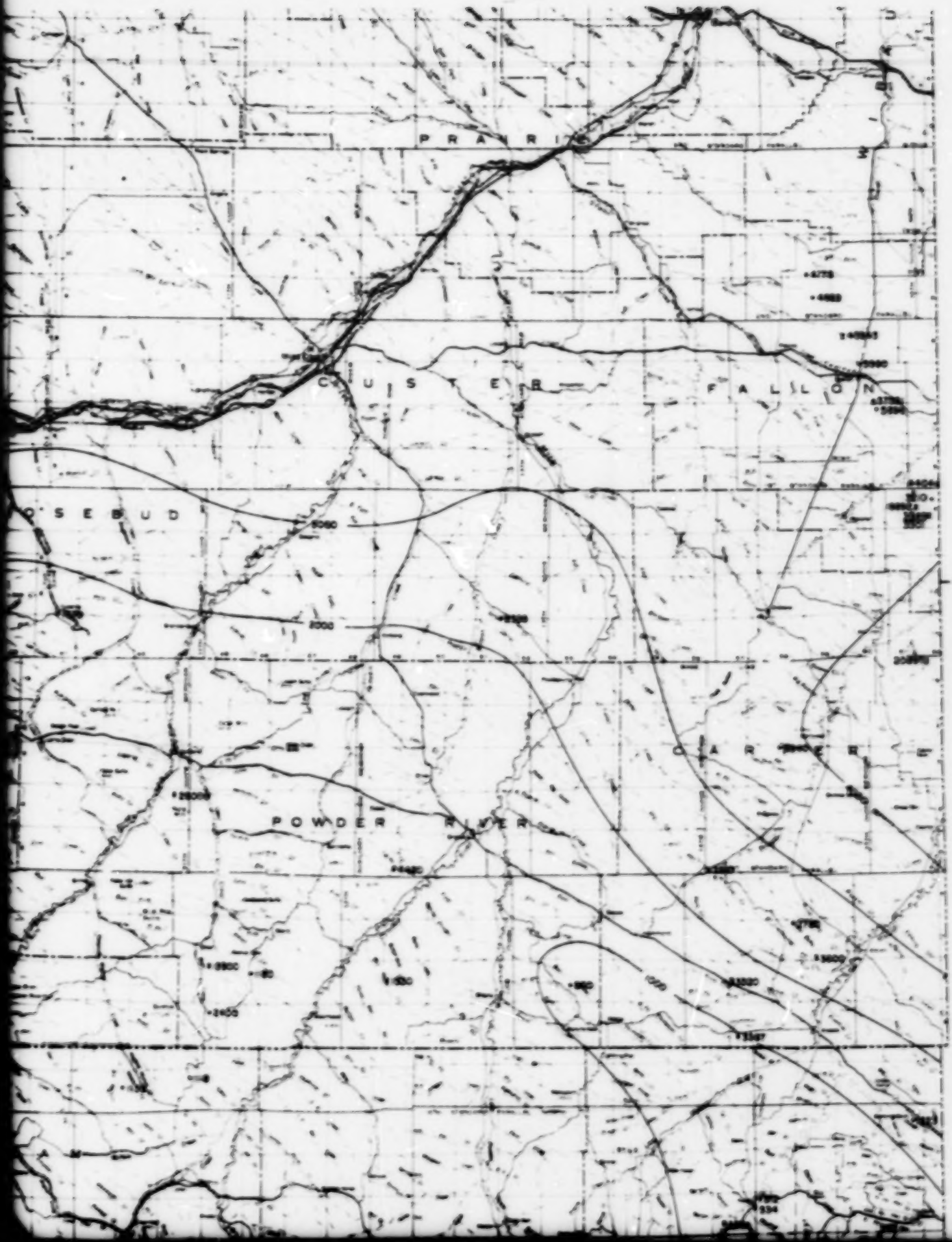
PLATE 2 - EQUAL-THICKNESS MAP OF THE MADISON GROUP, WITH SU
THICKNESS OF CARBONATE AQ



ADISON GROUP, WITH SUPPLEMENTARY FIGURES ON TOTAL
SS OF CARBONATE AQUIFER

D


TREASURE
ROSEBUD
POWDER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CUSTER
FALLON
SEBUD
POWDER RIVER

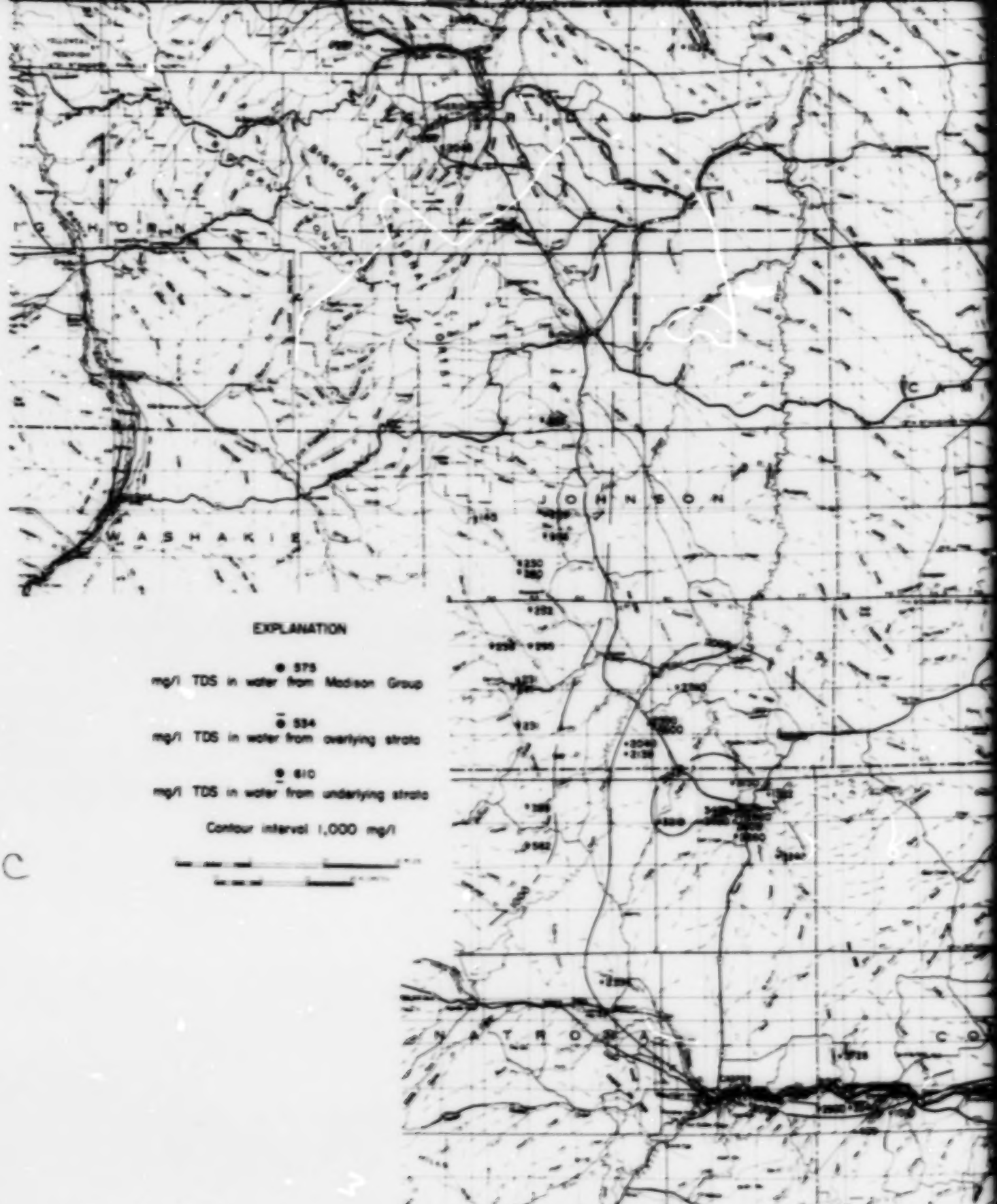
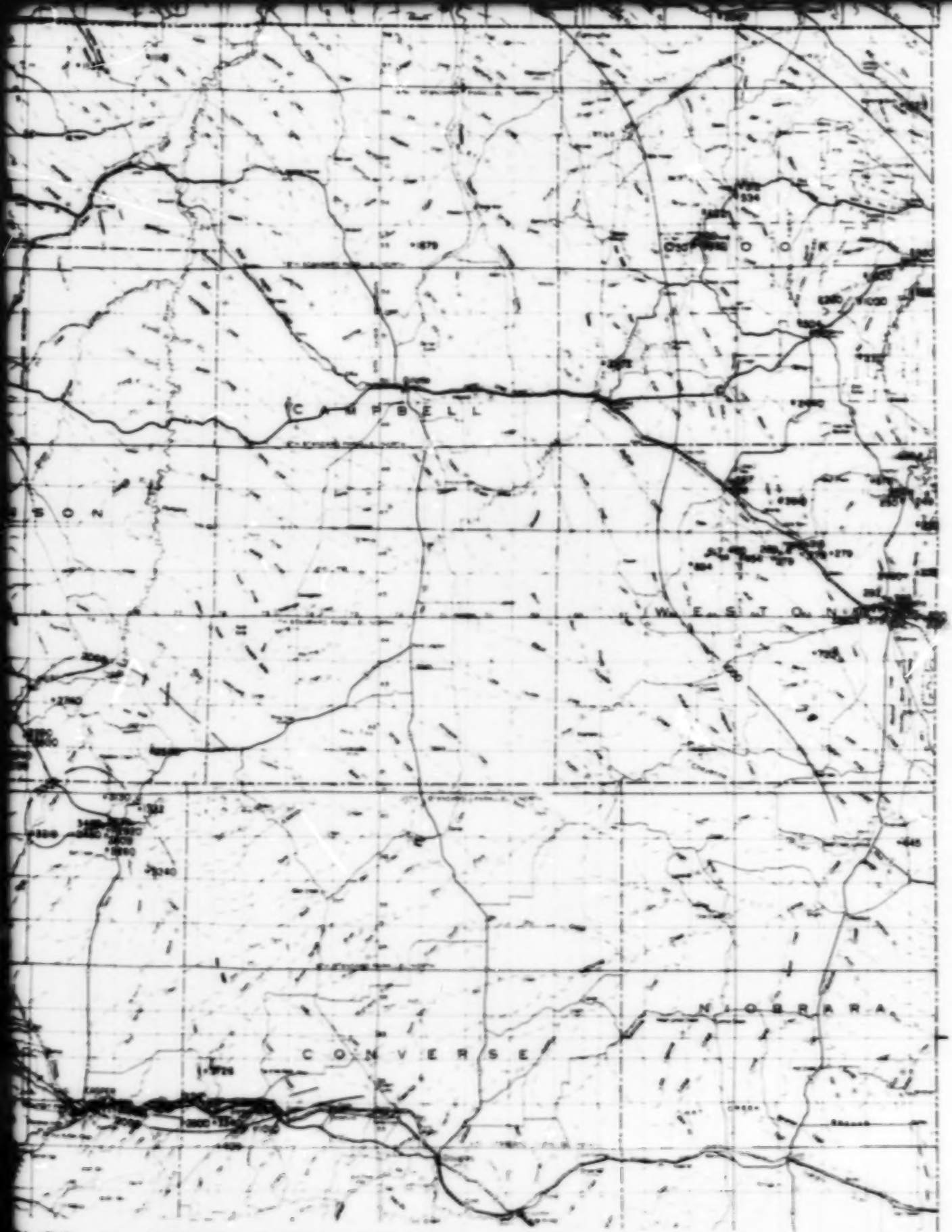


PLATE 3 - LINES OF EQUAL TOTAL DISSOLVED SOLIDS IN WATER FROM
DATA ON WATER FROM OVERLYING AND UNDERL



OLIDS IN WATER FROM MADISON GROUP, WITH SUPPLEMENTARY
OVERLYING AND UNDERLYING PARTS OF AQUIFER.

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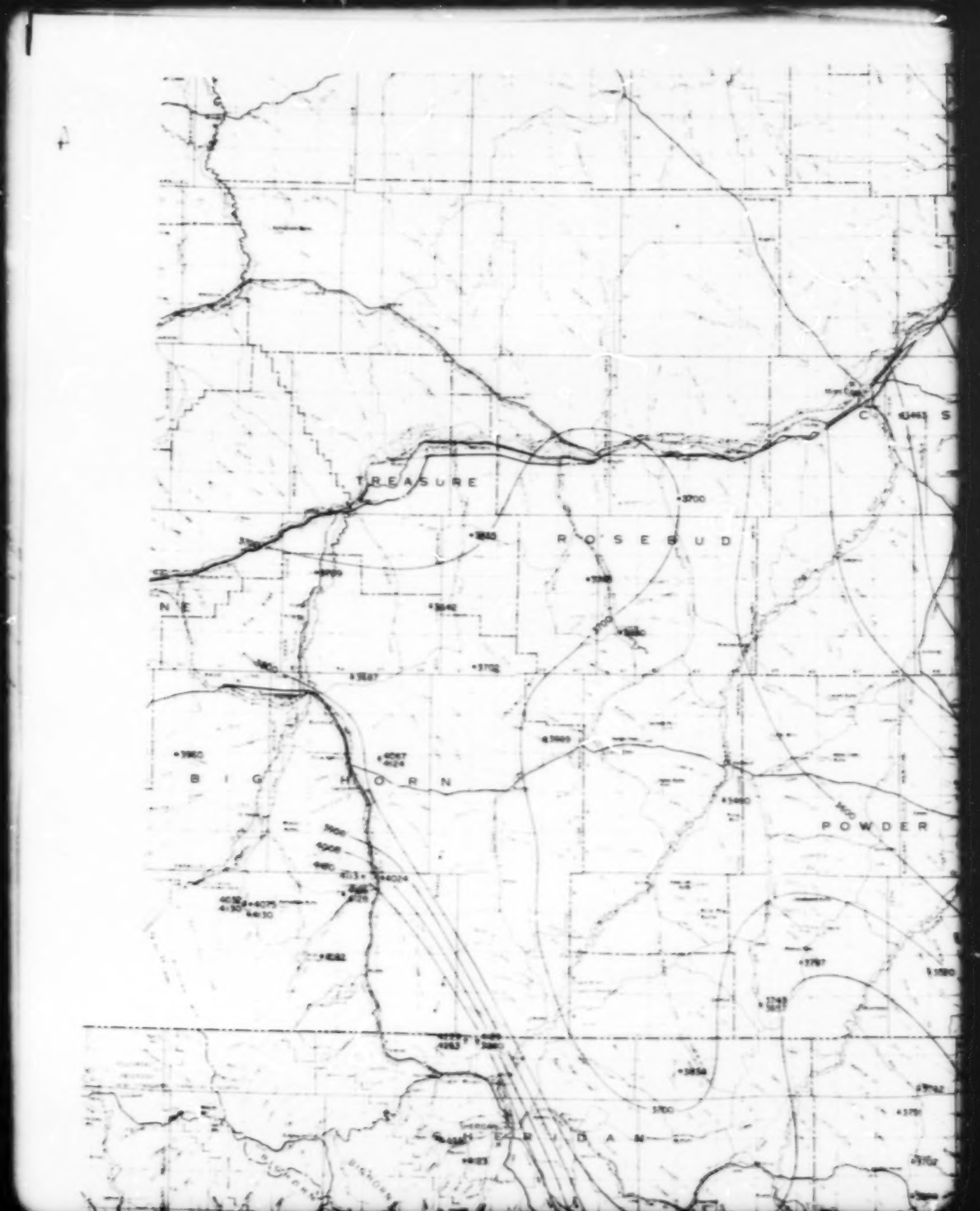
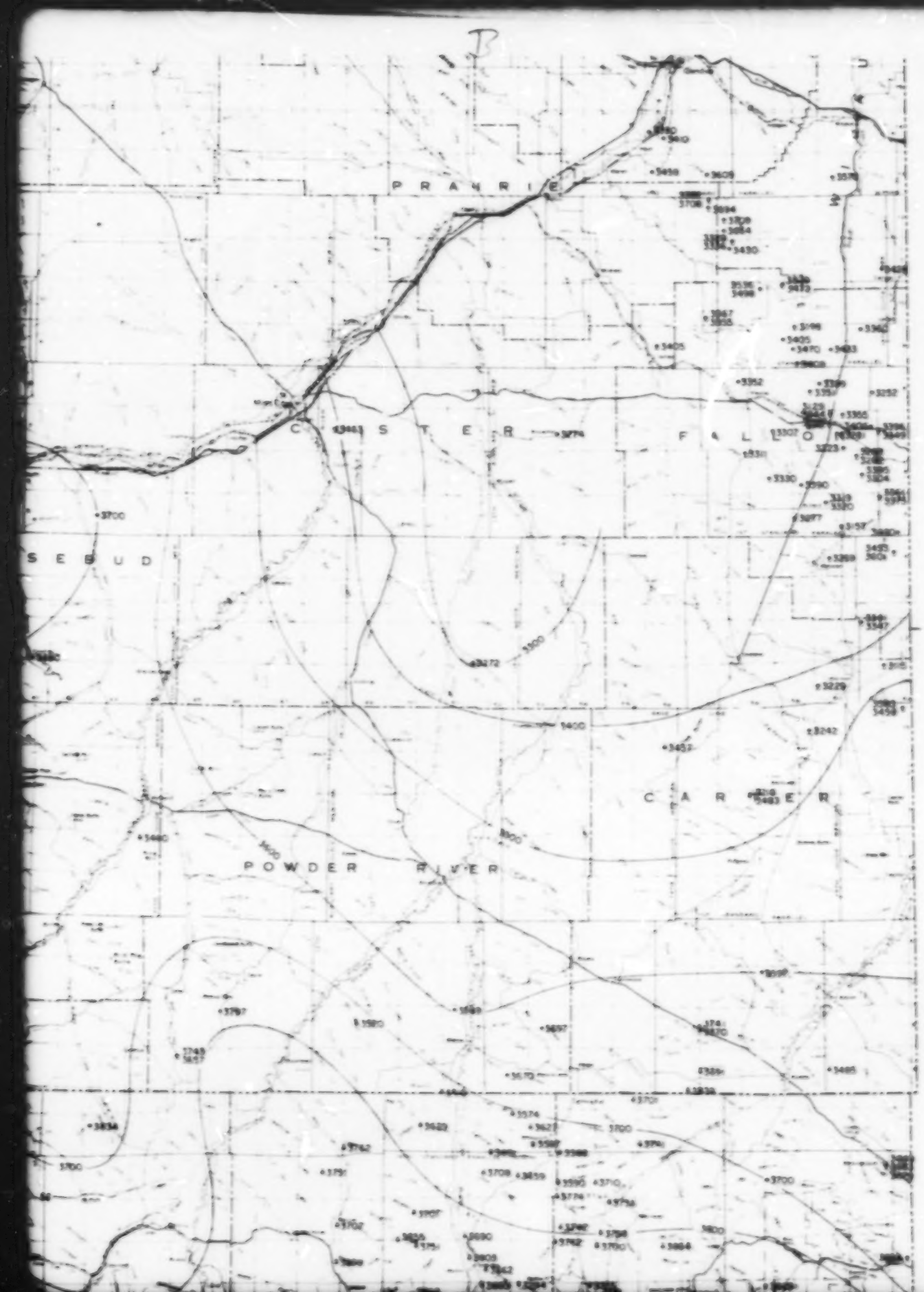

TREASURE
ROSEBUD
BIG HORN
POWDER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POWDER RIVER

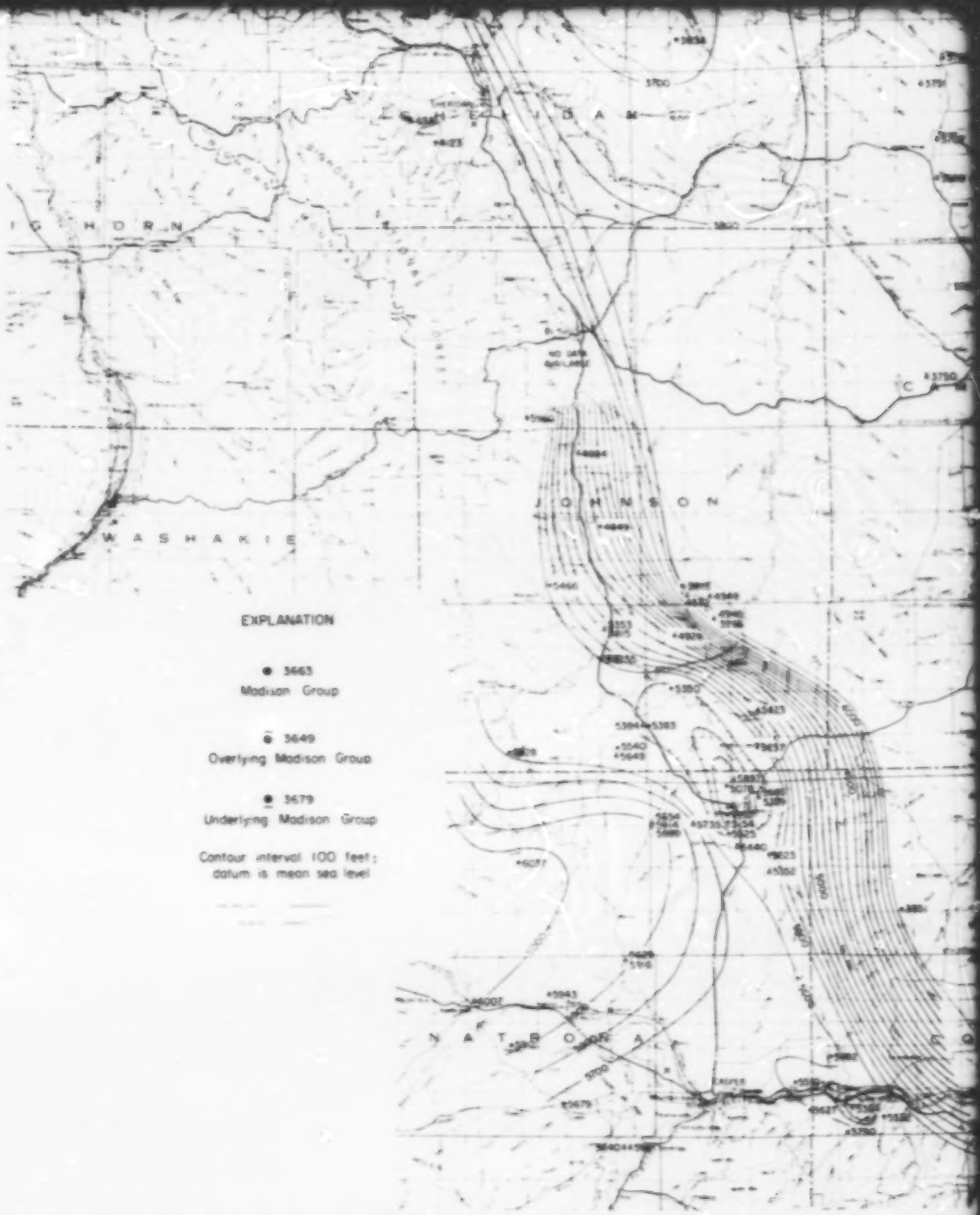
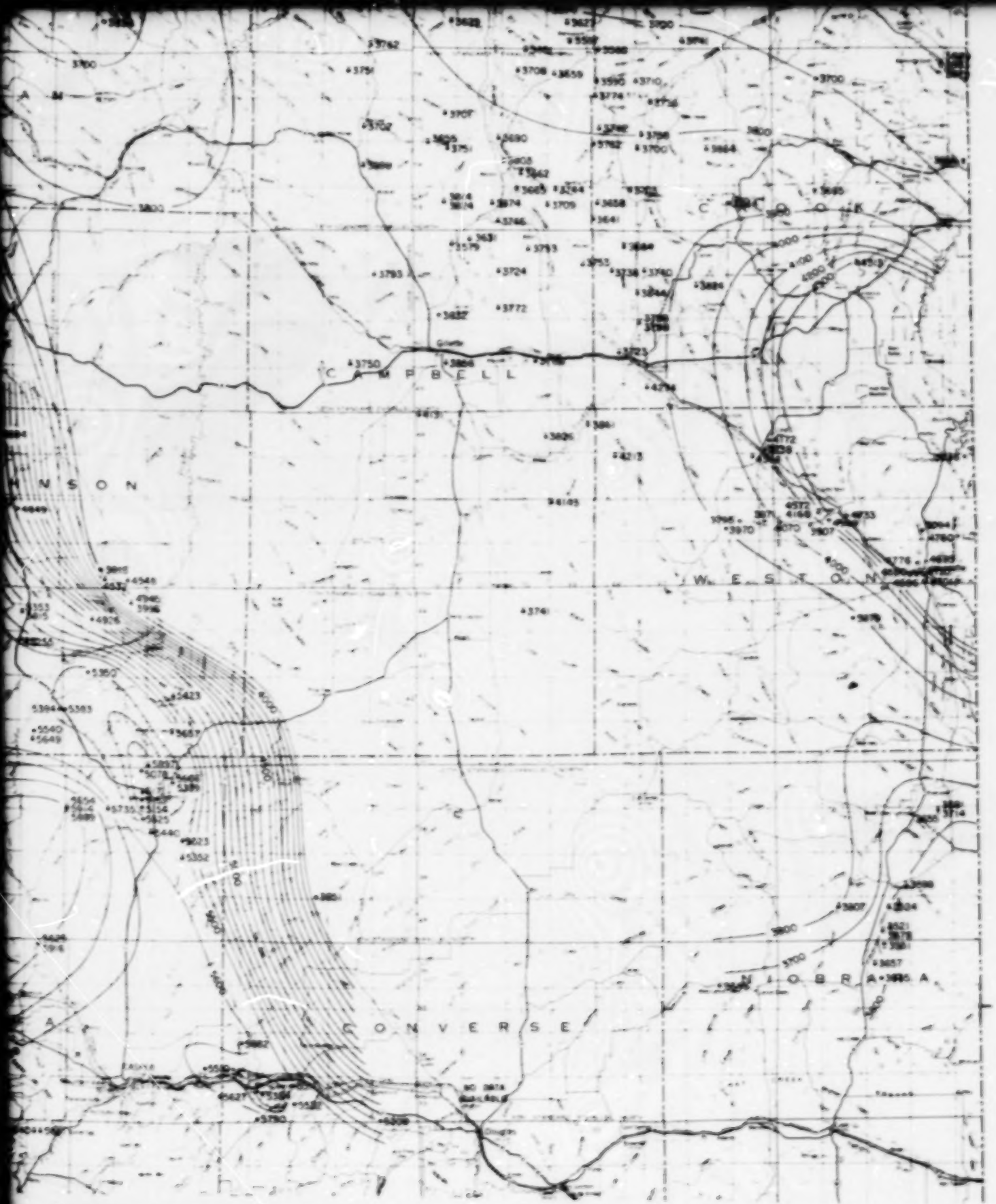


PLATE 4 - POTENTIOMETRIC CONTOURS SHOWING APPROXIMATE ALTITUDE
TIGHTLY CASED WELLS COMPLETED IN THE MADISON GROUP
POTENTIOMETRIC HEAD OF WATER IN OVERLYING AND UNDER



APPROXIMATE ALTITUDE AT WHICH WATER WILL STAND IN
IN THE MADISON GROUP, WITH SUPPLEMENTARY DATA ON
IN OVERLYING AND UNDERLYING PARTS OF THE AQUIFER.

D

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